APPENDIX D

INDEPENDENT CONSULTANT REPORT

BY

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Report to the U.S. Senate Committee on Veterans' Affairs
Special Investigative Unit on Gulf War Illnesses
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Part 1: Khamisiyah Event Modeling

INTRODUCTION

During the Aug. 1- Oct. 2, 1997 time period the SIU investigated the basis for a DoD/CIA press release of July 24, 1997, which indicated that approximately 98,910 U.S. troops in the Persian Gulf theater were exposed to low levels of nerve agent during March 1991. Briefings to Congressional staff, the press and the PAC on Gulf War Illnesses by Dr. Rostker (DoD) and Mr. Bob Walpole (CIA) revealed that a large geographic area covered by a "plume" of "sarin" originating from the destruction of M122 rockets in a pit at Khamisiyah, was determined by combining outputs from three different air dispersion models, which used meteorological inputs from two different mesoscale models and two different global-scale weather models. Rostker et al. reported a "plume" which represented the "union of five model/linkage results". The two global scale models were NOGAPS and GDAS, the two mesoscale models employed were COAMPS and OMEGA; the three transport/diffusion models were VLSTRACK, SCIPUFF and NUSSE. Appendix 1 contains a more detailed description of how these different computer codes were used in the overall modeling process. Several agencies which had originally developed these models for other purposes, were involved in the modeling effort. They are shown on an attached matrix diagram (in Appendix 1), provided by the Office of the Special Assistant for Gulf War Illnesses (OSAGWI, headed by Col. L. Chereghino).

This report evaluates the modeling methods which the CIA and DoD team used to characterize the potential release and dispersion of nerve agents from the pit area of Khamisiyah.

RESULTS

Meetings were held between the SIU and the DoD Office of the Special Assistant for Gulf War Illnesses (OSAGWI, headed by Col. L. Chereghino) and associated contractors (including SAIC, BDM) on August 14, 1997; with the Defense Special Weapons Agency (DSWA) on October 1, 1997; and with the Air Force Technical Applications Center (AFTC)/OSAGWI jointly, on October 2, 1997. Representatives from other agencies and organizations, including the Central Intelligence Agency (CIA) and the NRL (Naval Research Laboratory) attended some of these meetings as well. A meeting report(s) was prepared by the SIU with more details of attendees and proceedings. The following

comments are based on these meetings, and on briefings and written materials provided to the SIU. Since the July 1997 press release and briefings, the DoD/CIA has issued a report entitled "Modeling the Chemical Warfare Agent Release at the Khamisiyah Pit", CIA/DoD, Sept. 4, 1997, (Reference 1). This report has clarified or addressed several questions posed to the CIA and DoD since July 1997.

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• 1. The emphasis of the modeling efforts related to the Khamisiyah pit detonation, has been on meteorology and atmospheric dynamics. This is apparently due to the expertise of the contractors already under contract to the DoD and the CIA at the time the revised Khamisiyah effort was undertaken at the recommendation of the IDA review panel. Also, the IDA panel which reviewed the DOD and CIA modeling efforts in 1996 consisted mainly of meteorological experts (Ref. 1), so their recommendations focused on meteorological deficiencies.

While meteorology is an important aspect in reconstructing the Khamisiyah pit demolition or other similar events, other elements need to be included in the computations. In the modeling efforts to date, the omission of important chemical considerations has resulted in model results that very probably overestimate the dispersion of sarin and cyclosarin, by a considerable amount. The September 4 report (Ref. 1, pg. 20) estimates that combined losses of sarin through several chemical removal processes, could diminish the extent of the calculated "plume" by as much as 40%.

The chemical aspects which were not included in the modeling include:

a) Reaction of the liquid source reagent with wood debris, sand and other contaminants. Any decomposition of the spilled reagent would decrease the source term of reagent from the pit. A gradual evaporation of the spilled sarin/cyclosarin from wood and sand surfaces was modeled for as long as 72 hours. The length of time that viable material remained in the pit would be reduced by any decomposition reactions on surfaces.

b) Photolysis, or decomposition of the reagent by ultraviolet and visible radiation from the sun. The nerve agents are known to be unstable when exposed to UV/visible radiation. UV/visible photolysis could occur while the reagent is spread on the ground in the liquid phase, or when the reagents were in the gas phase, at any location to which they were transported.

c) Hydrolysis or reaction with water. This is a documented process for the destruction of liquid sarin. In the gas-phase a similar reaction is expected. This is particularly relevant since rain was reported (but not confirmed) during the second day of the period for which the modeling was performed. In any case, ambient water vapor (i.e. relative humidity) would need to be accounted for in the atmospheric chemistry.

d) Gas-phase reactions of the nerve agents with ambient atmospheric species. Reactions with background atmospheric species, which in the lower atmosphere/ ground level include ozone, hydroxyl radical, nitrogen oxides, molecular oxygen, water vapor (as noted in c), and others, need to be examined. The relatively large amount of sarin/cyclosarin released in one area could lead to appreciable reaction rates with some of these species. Since the time period of concern for troop exposure is several days (72 hours), even relatively slow reactions with ambient species need to be considered.

e) Gas-phase reactions of the nerve agents with contaminants introduced by the detonations and by the oil fires. The primary contaminant here would be smoke containing volatile organic compounds and particulates, although the other materials from the M122s could also be generated. The surfaces of carbon type particulates are known to facilitate decomposition type reactions of many compounds.

f) Thermal decomposition of the reagent. Thermal decomposition (due to solar heating during daylight hours) could occur either when the liquid was spilled in the pit and/or when the reagent was in the gas phase. Sarin thermally decomposes to form a variety of phosphorus containing compounds as well as propylene. The models assumed a certain amount of reagent was thermally destroyed upon detonation, based on simulant losses during the Dugway tests.

Any combination of removal processes would lead to a greatly reduced geographic extent of reagent dispersion. Col. Cereghino and DSWA representatives have indicated that the reason for omission of chemical kinetic schemes from the modeling effort to date was due to time constraints under which the modeling was performed. Chemical reaction rate constants for many of the processes described above are not available, therefore a considerable amount of time would be needed to generate some of these data in the laboratory.

The status of whether chemical kinetic and thermodynamic processes will be added to any of the models was discussed with the organizations involved. SAIC (August 14, 1997) reported that the relevant chemical kinetics data are simply not available at this time. However DSWA (Oct. 1 briefing) indicated that chemical kinetics would be added to the SCIPUFF model under a contract with Titan Aerospace Corporation, during the next year (FY98). This doesn't seem likely if the data do not exist or if numerous experiments are needed to obtain the data. Lists of Federally funded research projects (e.g. those in the PAC report on Gulf War Illnesses)have not revealed any projects directed to study the chemical reactivity of nerve agents outside of the human body. In the September 4, 1997 report, the "Next Steps" section does not include any plans to either perform experiments to provide information on nerve agent reactivity nor to incorporate chemical mechanisms into the models in the future.

2) The focus on meteorology by personnel assigned to the modeling effort has also hindered our investigation into the modeling of the Khamisiyah demolition process. We have not been able to obtain a detailed explanation of how the destruction processes in the pit were modeled, including what thermodynamic parameters and chemical reactions were included. Rather, the information presented to us has focused on the meteorology which affected the dispersion of reagents several hours after the demolition occurred.

3) Since the IDA panel completed their review, several enhancements to the modeling process have been made by the DoD OSAGWI/CIA team. These are described in Ref. (1) and in briefing materials provided in July 1997. In particular, tests performed at Dugway Proving Grounds in May 1997 helped the team refine their estimates of the amount of sarin which likely survived the Khamisiyah detonation, the extent of aerosolization and evaporation of the reagent and the extent of dispersal of reagent. This was done primarily through measuring amounts of simulant collected at the Dugway site, and comparing that to the amount originally in the M122s (i.e. through the mass balances). In August 1997 the SIU received a draft report of the Dugway test results. (Draft Data Report for the Demolition Characterization Test of the 122-Millimeter Chemical-Fill Rocket, C. L. Nudell et al., Chemical Test Division, U.S. Army Dugway Proving Ground, June 1997, (Ref.2)). The Dugway tests are described in more detail in earlier SIU reports. Ref. 2 mainly consists of data from the various collection locations and detectors at the Dugway test site. The tests were scaled-back versions of the Khamisiyah detonation and as such were only used to obtain fundamental information about the M122 destruction mode and the simulant mass balance. The detectors and collectors were placed relatively close to the detonation site at Dugway, so long-range or mid-range dispersion information was not obtained.

- 4) An unresolved but important aspect of the modeling is whether or not any of the sarin/cyclosarin gas rose above the boundary layer (also known as the mixing layer) either at the time of the initial injection above Khamisiyah or at some other location, such as near the Persian Gulf. The assumption made in each combination of dispersion models as to the main altitude of reagent transport was fundamental to the end results produced by the models. An independent set of models, run by AFTC for the Khamisiyah scenario illustrated this difference. Generally, the DoD/CIA group assumed that the reagent did not go above the altitude of the boundary layer (Ref. Walpole discussion with SIU Oct 2, 1997 at OSAGWI office). This assumption contributed to the OSAGWI conclusion that on "Day 2", the reagent had moved southward and then westward for several hundred miles from Khamisiyah. The AFTC model which utilized high altitude winds indicated that on the second day, at least some of the reagent would have been blown over the Persian Gulf, in an eastward direction.
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While this issue may not get resolved for the particular Khamisiyah event, it is important to recognize inherent uncertainties in the modeling efforts, particularly those which are based on selected parameters (such as wind altitude and direction). The SIU (Jim Moore) has requested that additional computations be performed by AFTC for further comparison with the other modeling results of the OSAGWI/CIA group.

5) In presenting the modeling results to the public, to Congressional staff and to veterans, the DoD and CIA chose to combine five different modeling results and draw a perimeter around the outer edge of the geographic areas where low levels of nerve agent were determined to have penetrated. That is, the broadest possible area of potential exposure was presented, even though within that area, the models results did not necessarily overlap after "Day 1". The SIU has questioned the validity and the confidence placed on selecting a union of potentially affected geographic areas, versus selecting a smaller intersection region where the models do agree.

We have made several requests to OSAGWI/CIA for statistical analyses and confidence limits associated with their reported affected geographic boundaries. They have responded that such analyses were not performed and/or are not available. However the Sept. 4 1997 report (Ref. 1) and Mr. Walpole (Oct. 2, 1997 discussion) indicate that they "modified the models to broaden the contours so that they predict that there is a 99% probability that a given dosage will fall within a given contour". Further clarification is needed to ascertain whether those modifications increased the accuracy and precision of the modeling, or just resulted in a larger area within the contour lines.

6) The DoD/CIA have indicated that their selection criteria for the dispersion models used included previous validation (see Appendix 1), suitable time increment acceptability, suitable geographic grid size and ease of linkage with larger meteorological models. The validation of certain models was reported to be the basis for the confidence placed in the models. Validation of the models is absolutely necessary. However for the Khamisiyah case, the models were used to predict the location of reagent as far as approximately 200- 300 km from the release site and at very low levels of reagent (at or below .01296 mg-min/m^3 or "low level exposure area"). There are very few validation exercises and probably not those performed within the Continental U.S. (e.g. at White Sands Missile Range or in Georgia) for the VLSTRACK and SCIPUFF which make in situ measurements for such great distances away from a source of reagent. Validations were likely not performed for such low level, sporadic doses of reagent over such great distances as in the Khamisiyah case. To date there have not been any known dosages or chemical detections in the Persian Gulf against which to validate the predictions made for Khamisiyah.

7) In several instances, terminology used by Rostker and Walpole in their briefings and information releases was misleading. The meaning of what was presented has since been discussed with the SIU. However other persons receiving the initial July 1997 press release have likely not had the benefit of any clarification unless they received the Sept. 4 1997 DoD/CIA report.

a) The term "plume" was used throughout the briefings in July 1997, in the press releases, at subsequent meetings and in the Sept. 1997 report, to describe the boundaries drawn on maps of the Persian Gulf region to illustrate areas of potential exposure to sarin and cyclosarin. The implication was that a column or band of reagent had spread as far as 200-300 km south and west of Khamisiyah, over a three day period. Actually the models predicted areas where nerve agents may have been transported sporadically and in small air parcels discontinuously over a 72 hour period. The maps and figures compiled by OSAGWI/CIA actually showed accumulated dosages of reagent, not the spread of a single "plume" or cloud. Furthermore, the figures were composites, illustrating the union of dosages predicted by several models, not the location of a single "plume" of any sort.

b) LD50 and LCt50 exposure criteria were presented in the briefings (see first chart of July 24 1997 briefing package, also attached to this report) given by Walpole and Rostker (see attached chart) as simply lethal dose and incapacitation dose limits of 100 mg-min/m^3 and 35 mg-min/m^3 respectively. In fact these terms are defined (Ref. Material Safety Data Sheets with U.S. Army data) as levels at which more than 50% of the population under defined breathing conditions would die or would be incapacitated. That is, even at those dosages, not 100% of exposed humans would die or be incapacitated.

Short term exposure criteria (LD50 and LCt50) were combined with longer term exposure guidelines for "first noticeable effects" and the "general population limit" on the same figures. This is confusing because these criteria have different applications with different time constraints. The maps released to the press and the public by DoD/CIA did not indicate the relevant time periods of exposure associated with each of the different limits. Presumably the use of these different types of standards was meant to convey that no one was exposed to the higher critical dosages of nerve agent.

c) One of the charts presented for public dissemination by OSAGWI/CIA in July 1997, included the phrase,

- "Many soldiers were exposed at a very low level unlikely to produce long term health effects—medical research continues"

This chart and other material released in July 1997, implied a 100% certainty that many soldiers were exposed to a low level of nerve agents. First, there is not conclusive evidence that nerve agents were release on March 10, 1991 at the Khamisiyah pit since no troops reported exposures or alarms. Second, the models indicate that a certain percentage of people

in the area may have been exposed, but as described above, there are considerable uncertainties (both systematic and statistical) associated with the model results. Third, the DoD/CIA team (Ref. Oct 2 discussion with Bob Walpole) have indicated that there were regions within their released "plume" boundaries that the models predict were not exposed to any reagent at all. Therefore the wording used in many instances by the DoD/CIA which implied that some troops were definitely exposed is misleading.

SUMMARY

Many of the questionable elements of the modeling effort have been attributed by Col. Cereghino et al. to the stringent schedule imposed by the PAC. OSAGWI and the CIA were obligated to release data on Khamisiyah in July 1997. In light of the uncertainties and missing elements in the models, the release of troop exposure numbers and locations in July 1997 seems premature. There has been no firm indication that future near-term DoD/CIA modeling efforts for other potential chemical releases during or after Operation Desert Shield/Desert Storm will have any more certainty associated with them.

Part II: FOX Vehicle Procedure Update

Appendix II contains an updated procedural review of the FOX vehicle and associated chemical detection devices, based on field demonstrations performed during an SIU visit to Edgewood on September 30, 1997. This summary was also included as part of a trip report prepared by Vince Averna of the SIU.

Appendix I: Summary of Khamisiyah Modeling Procedures (OSAGWI and CIA)

The CIA and DoD released a report, "Modeling the Chemical Warfare Agent Release at the Khamisiyah Pit, on September 4, 1997. That report highlights the main elements of the effort to reconstruct the events and processes that occurred following the demolition of M122s in the pit at Khamisiyah. The Sept. 4 report, from which most of the information here is extracted, provides back-up information which was not available to the public in July 1997. The DoD/CIA modeling group use a model matrix diagram to illustrate the relationships between large scale weather inputs, mesoscale meteorology models and higher resolution transport and diffusion models. This matrix is attached here and is also available in Ref. 1 and numerous briefing packages.

Global weather forecasts were obtained from the Global Data Assimilation System (GDAS) in March 1991 and were more recently generated for the March 1991 time period using the Naval Operational Global Atmospheric Prediction System (NOGAPS). These large-scale systems use inputs from rawinsondes, surface data, ship data and satellite data. The DoD/CIA has improved and extended their sources of raw weather data for March 1991, since the IDA panel review of their modeling efforts.

GDAS and NOGAPS were used to set initial boundary conditions for three "mesoscale" models: The Coupled Ocean Atmosphere Mesoscale Prediction System (COAMPS), the Operational Multiscale Environment Model with Grid Adaptivity (OMEGA) and the Fifth Generation Penn State/NCAR Mesoscale Model (MM5). Mesoscale refers to processes which occur on the scale of approximately 1-100 km in horizontal extent. These three codes model planetary boundary layer (mixing layer) dynamics and were used to predict wind speeds and directions throughout the region of interest. The models included the effects of terrain, Persian Gulf Sea Breezes and moisture on the atmospheric dynamics. They did not include any atmospheric chemistry. Various combinations of the global inputs (GDAS and NOGAPS) with the three regional models were tested for sensitivity to input parameters. The models were validated by attempting to duplicate oil fire smoke trajectories known from observed soot patterns. The combinations eventually chosen to model dispersion from the Khamisiyah pit were:

a) NOGAPS/COAMPS
b) GDAS/OMEGA
c) GDAS/MM5

Three transport and diffusion models were used to model the dispersion of reagents from Khamisiyah: the Second-Order Closure Integrated Puff (SCIPUFF) model from the Defense Special Weapons Agency, the Vapor Liquid and Solid Tracking (VLSTRACK) model from

Naval Surface Weapons Laboratory, and the Non-uniform, Simple Surface Evaporation Model (NUSSE4) model, from the CIA. Of these, VLSTRACK has been validated against field data for 60 chemical, biological or simulant releases while SCIPUFF has been validated in tests at the White Sands Missile Range, according to Ref. (1) . NUSSE 4 appears to be the only model that was able to handle multiple reagents (needed to model both sarin and cyclosarin) but it did not include terrain features as the other models did.

Each of the three transport and diffusion models assumed an initial stack of 13 M122s distributed along a 300 meter long line. The initial release of reagent was assumed to be half way up the stack or at approximately 1 meter from the ground. Based on the Dugway test results, it was assumed that 19 gallons of reagent was vaporized, 19 gallons was released as droplets, 108 gallons spilled on the soil and later evaporated, and 196 gallons spilled on wood and later evaporated. Additional amounts were spilled on the soil and wood and retained (174 and 86 gallons respectively) or were destroyed in the blast (151 gallons). The models accounted for the initial release of vaporized reagent as well as subsequent evaporation from the surfaces. Laboratory experiments were performed at Dugway and at Edgewood in the May- July 1997 time period, to quantify the characteristic rates of sarin and cyclosarin evaporation from sand and other materials.

Five combinations of models were used to predict geographic areas of exposure to the reagents. The combinations were:
a) NOGAPS/COAMPS/SCIPUFF
b) GDAS/OMEGA/SCIPUFF
c) NOGAPS/COAMPS/VLSTRACK
d) GDAS/MM5/SCIPUFF
e) GDAS/OMEGA/NUSSE4

A union of five geographic areas defined by the models was selected by the DoD/CIA as the area for troop notification of potential exposure. The five model results were reported for Day 1-3 after the Khamisiyah detonation. Final exposure contours, that is, regions where cumulative dosage levels were indicated, were presented from the model results. The contour line levels were termed "first noticeable effects" and "low level exposure area". Differences in the model results have been largely attributed to "turbulence-induced uncertainties".